THE ENERGY EFFICIENCY AND EMISSIONS BENEFITS OF EE PROGRAMS: AN INTEGRATED ANALYSIS

Overview of Results

This study utilizes an integrated model to estimate the benefits of EE's programs on energy efficiency and emissions. We chose an integrated model to estimate the benefits of EE programs because it allows us: (1) to ensure an internally consistent analysis across all EE sectors; (2) to avoid double counting; and (3) to incorporate the interactions and tradeoffs between competing technologies and uses. In addition to understanding the benefits of the EE programs, the study fulfills requirements contained in both the Government Performance and Results Act of 1993 and the Vice President's National Performance Review.

The integrated results recognize the interaction effects of EE programs in four sectors: the Office of Building Technologies (OBT); the Office of Industrial Technologies (OIT); the Office of Transportation Technologies (OTT); and the Office of Utility Technologies (OUT). We did not include programs from the Office of Technical and Financial Assistance (OTFA) in the integrated analysis due to the difficulty of isolating their impacts from those of the OBT programs. In addition, OTFA programs are not technology based and are therefore more difficult to include in engineering and economic models. In next year's Quality Metrics (QM) analysis, we hope to be able to include the OTFA programs.

Three computer models contributed to the integrated assessment of the EE programs. First, we used the Integrated Dynamic Energy Analysis Simulation (IDEAS) model as an integrating framework to estimate the benefits of the EE programs in the buildings and transportation sectors. IDEAS is a national energy policy model maintained by the Policy Office at DOE and has been used most recently as the integrating framework for the Climate Change Action Plan. Second, we relied upon the Industrial Model for Energy Analysis and Forecasting (IMEAF) model, a version of the National Energy Modeling System (NEMS) industrial model, to analyze the benefits of the EE programs in industrial sector. And third, we utilized the Dynamic Energy and Greenhouse Emissions Evaluation System (DEGREES) model to assess the benefits of the EE programs in the utility sector.

The IMEAF and the DEGREES models allow for more detailed analyses in their respective sectors than the IDEAS model. For example, the IMEAF model permits analysts to examine the industrial sector by SIC industry. This is necessary to analyze the industrial sector planning units. The DEGREES model allows researchers to assess the regional representation of the electric utility sector. This is important because utility markets are characterized by their diversified resources and regional transmission systems. Recognizing the model differences, we used the results from the IMEAF and DEGREES models as inputs to the IDEAS model in the industrial and utility sectors, enabling the IDEAS model to generate the integrated analysis results.

We developed two EE cases to estimate the benefits of EE programs: (1) a “No-EE Case" that assumes no EE programs are implemented; and (2) a “Full-EE Case” that assumes the EE programs meet their goals and objectives. The difference between the energy and emissions projections of these two cases is the savings created by the EE programs. We constructed the No-EE Case by starting with the input assumptions from EIA's 1994 Annual Energy Outlook (AEO94) and then removed elements of EE programs (e.g., 1998 proposed standards and EPAct standards) that were included by EIA in those assumptions. We allocated the energy savings (mainly electricity) in the integrated Full-EE Case to the individual sectors. The most difficult allocation was for non-renewable energy used to produce electricity because energy efficiency programs reduce the demand for electricity, thereby decreasing the use of energy for electricity production. An increase in renewable energy also reduces non-renewable energy consumption. Due to these factors, we divided the total savings from utilities into these effects and allocated to OBT, OIT, and OUT appropriately, taking into account the interactive and overlapping effects of these programs. Allocation within a sector to individual planning units was also required. For some sectors, the models could be run with one planning unit at a time, and then the individual savings would be allocated to the combined total. In other sectors, the planning units were so interwoven that savings could only be allocated based on the total savings and other factors. In the buildings, industry, and utility sectors, the individual planning unit subtotals are not the same as the allocated integrated savings. These totals represent each sectors' estimate without the impact of the other sector programs in order to be consistent with the Sector Office estimates.

In general, the integrated model projected lower energy savings and emissions levels than the individual sector projections. These differences are partially attributable to the interaction effects of the planning units included in the integrated model. In contrast, the sector models estimate only for the planning units in their sector and did not take into account any interaction effects with other sector planning units. For example, in the Full-EE Case, OBT and OIT conservation programs reduce electricity demand, and thereby decrease the potential market for OUT renewable energy technologies. This interaction effect causes the integrated model OUT energy savings projection to be lower than the OUT sector projection that does not recognize the reduction in electricity demand resulting from OBT and OIT programs.

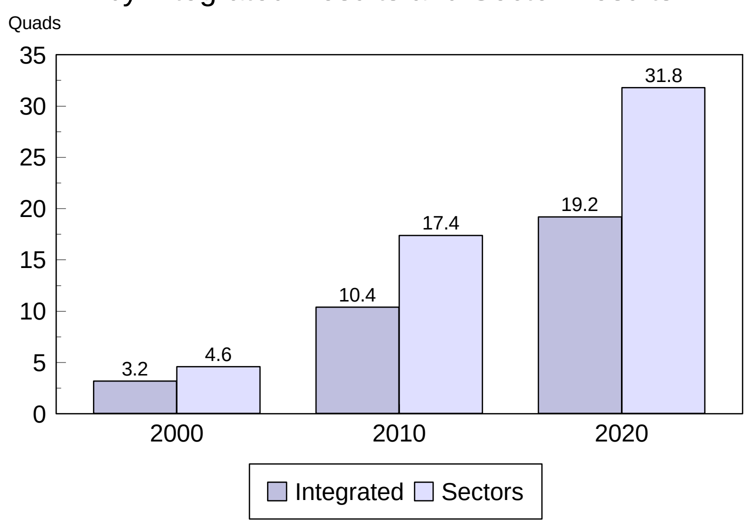
BENEFITS OF EE PROGRAMS

The integrated model estimates that the total primary energy savings from EE programs will increase from approximately 3.2 quads in 2000 to 19.2 quads in 2020 (see Table 1-1). By contrast, the sector results estimate that the EE programs will save more energy, totaling 4.6 quads of energy in 2000 and increasing to 31.8 quads in 2020 (see Figure 1-1). At the sector level, comparisons between integrated and sector results are for illustrative purposes only since the sector results do not include interaction effects and assume "all-else equal." The difference provides information about interactions and double counting.

In terms of carbon emissions reductions, the integrated model estimates that EE programs will save approximately 56 million metric tons of carbon (MMTC) in 2000. By the year 2020, this figure is expected to increase to approximately 406 MMTC (see Table 1-2). Just as in the energy use case, the sector results estimate that the EE programs will save a larger amount of emissions than the integrated results, i.e., 71 MMTC in 2000 and 530 MMTC in 2020 (see Figure 1-.2)

Table 1-1. Total Primary Energy Savings Projections[1] (Quadrillion Btu)										
Year	**OBT**		**OIT**		**OTT**		**OUT**		**Totals**	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results[2]**	**Sector Results**	**Intgtd. Results[3]**	**Sector Results**
2000	1.7	2.6	.7	.94	.2	.3	.6-.4	.8	3.2	4.6
2010	4.5	6.4	2.4	3.9	2.4	3.1	1.1-1.9	3.9	10.4	17.4
2020	6.0	9.9	4.0	8.4	5.8	6.1	3.4-5.0	7.4	19.2	31.8

Figure 1-1. Energy Use Benefits of EE Programs by Integrated Results and Sector Results



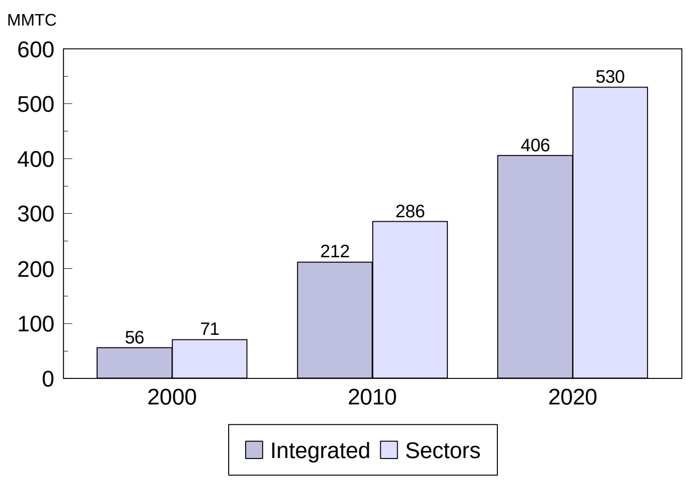
[1]Estimates rounded to the tenth decimal place.

[2]A range is presented for the OUT integrated results because we ran the integrated model with and without the OBT and OIT program energy demand impacts. The first digit in the range includes the OBT and OIT program energy demand impacts (hereafter referred to as the "OBT-OIT Impacts Case"), while the second digit in the ranges excludes those demand impacts (hereafter referred to as the "No OBT-OIT Impacts Case). As OBT and OIT planning units met their goals and objectives of increasing energy efficiency, total energy demand was decreased, thereby reducing the need for generation capacity. This in turn reduced the impact of the OUT programs on energy efficiency. The range thus enables the reader to see what impact OUT's programs will have on energy savings if OBT and OIT's planning units meet all their goals and objectives as well as if OBT and OIT's planning units partially meet their goals and objective.

[3]The total is based on the first figure in the OUT integrated estimate range.

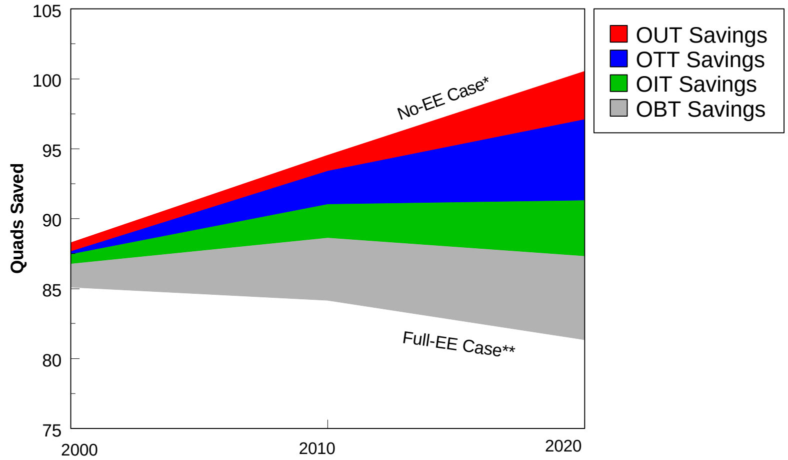
Table 1-2. Total Carbon Equivalent Emissions Savings (Million Metric Tons of Carbon)										
Year	**OBT**		**OIT**		**OTT**		**OUT**		**Totals**	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
2000	33.3	38.0	8.8	9.9	6.3	7.6	7.2-4.8	12.0	55.6	71.0
2010	97.0	97.0	34.4	40.3	50.8	71.0	30-52	61.7	212.2	286.0
2020	133.8	158.0	68.9	92.5	128.2	137.0	75.5-111	123.6	406.4	530.0

Figure 1-2. Carbon Emission Benefits of EE Programs by Integrated Results and Sector Results



The integrated model projects that OBT will be the EE sector with the largest total primary energy savings in the year 2000, totaling 1.7 quads (see Table 1-1). Energy savings in the other EE sectors range from 0.2 quads in OTT to approximately 0.7 quads in OIT and 0.4 to 0.6 quads in OUT. OBT will continue to have the largest energy savings in the year 2010, although we expect that the proportional savings gap between it and OIT will decrease from approximately 140 percent in the year 2000 to 90 percent. By the year 2020, OTT is expected to have a primary energy savings comparable to OBTs (6 quads and 5.8 quads, respectively) (see Figure 1-3). Sector carbon reductions follow a 20 year trend similar to the sector primary energy savings with OBT having the largest emissions reduction in the year 2000 and OTT attaining an emissions reduction comparable to OBT's in the year 2020 (see Table 1-2).

Figure 1-3. Benefits of EE Programs,
Non-Renewable Primary Energy Savings



*Energy consumption projection level based on no EE program impacts.
**Energy consumption projection level assuming EE programs meet goals and objectives.

SHORT-TERM AND LONG-TERM BENEFITS OF EE PROGRAMS

All of the sector planning units make some contribution to the total energy savings figures in Table 1-1. A number of planning units, however, provide greater short-term energy savings, while others contribute more toward long-term energy savings. The reasons for these differences vary from technology factors, such as the maturity of the technology, to market factors, such as the market potential of the energy efficient product.

In OBT, we expect the combination of Building Standards, Building Systems R&D, FEMP, and Implementation & Deployment to have the largest primary energy savings in the year 2000, equaling 0.94 quads (see Table 1-3). By the year 2020, however, the integrated model projects that the combination of Building Standards, Building Systems R&D, FEMP, and Implementation & Deployment and the combination of Lighting/Appliance Standards and Light/Appliance R&D will each have a primary energy savings of 2.67 quads. In both these planning unit groups, efficiency standards and Climate Change Actions comprise most of the near term savings. In the long term, R&D contributes significant savings as well.

Table 1-3. Primary Energy Savings by OBT Planning Units (Quadrillion Btu)						
	2000		**2010**		**2020**	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
Building Env R&D	.07	.04	1.15	.4	1.81	1.03
Heating/Cooling Eqpt R&D		.71		1.5		2.63
Building Standards		.24		.52		.87
Building Systems R&D	.94	.28	2.03	.65	2.67	1.15
FEMP		.13		.19		.19
Implmtn & Deploymnt		.14		.15		.15
Lighting /Appliances Stds	.78	.96	1.88	2.43	2.67	2.71
Lighting /Appliances R&D		.04		.57		1.13

In OIT, we estimate that the Municipal Solid Waste and the Industrial Wastes planning units will have the largest short-term sectoral energy savings, each totalling approximately 0.3 quads in the year 2000 (see Table 1-4). In the long-term, however, we estimate that the Industrial Wastes and Metals and Materials planning units will have the greatest energy savings, equaling 2.07 quads and 1.21 quads in the year 2020, respectively. Advances in industrial technologies, such as electrolysis of neodymium metals, are driving the long-term energy savings in the industrial sector.

In OTT, the integrated model estimates that the Materials Development and the Biomass Fuels planning units will have the largest short-term energy savings, equaling 0.12 quads and 0.10 quads in the year 2000, respectively (see Table 1-5). In the long-run, we estimate that these planning units will continue to have the largest energy savings, however, their order will flip-flop in the year 2020 with the Biomass Fuels planning unit having the largest energy savings (2.11 quads), followed by Materials Development (1.58 quads). Anticipated infrastructure developments that are likely to lead to lower fuel prices and increased accessibility to biomass fuels are contributing to the primary energy savings of the Biomass Fuels planning units, while expected R&D advances in light-weight materials account for much of the savings coming from the Materials Development planning unit.

Table 1-4. Primary Energy Savings by OIT Planning Units
(Quadrillion Btu)

	2000		2010		2020	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
Chemicals & Petroleum	.0012	.008	.02	.04	.04	.07
Cogen [4]	.07	.02	.15	.17	.45	.54
Electric Motors[5]	.04	.07	.12	.34	.24	..37
Implment & Deploymnt	.007	.02	.01	.02	.02	.02
Industrial Wastes	.29	.39	1.12	1.82	2.07	3.58
Metals & Materials	.04	.05	.32	.44	1.21	1.50
Municipal Solid Waste	.3	.34	.6	.66	.7	.98
Process Htg & Cooling	.01	.03	.08	.22	.12	.3
Pulp & Paper	.001	.002	.01	.02	.02	.03
Solar Industrial Applns	.005	.007	.12	.17	.70	1.01

Table 1-5. Primary Energy Savings by OTT Planning Units
(Quadrillion Btu)

	2000		2010		2020	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
AFV Demos	.00	.01	.10	.02	.37	.03
Biomass Fuels	.10	.00	.96	.82	2.11	1.86
Electric Veh Bttries/Sstms	.00	-.01	-.01	-.05	-.02	-.06
Fuel Cell Vehicles	.00	.00	.03	.05	.42	.42
Heavy Duty Transport	.02	.04	.26	.50	.54	1.36
Hybrid Vehicles	.00	.00	.18	.24	.75	.74
Implmtn & Outreach	n/m	.06	n/m	.17	n/m	.25
Materials Development	.12	.2	.91	1.39	1.58	1.47

[4] Applied at 1/3 attribution rate to OIT.

[5] Applied at 20% attribution rate to OIT.

In OUT, the integrated model estimates that the Biomass Technologies planning unit will make the largest contribution to energy savings in the year 2000, totaling somewhere in the range of 0.2 to 0.5 quads (see Table 1-6).[6] We estimate that the Geothermal Technologies and the IRP planning units will make the next largest energy savings contributions, each saving 0.16 quads (based on OBT-OIT Impacts Case range estimates). In the year 2020, we estimate that the Geothermal Technologies planning unit will account for the largest energy savings (based on a low range estimate of 0.98 quads), followed by Wind Technologies and Solar Technologies at 0.84 quads and 0.78 quads (OBT-OIT Impacts Case ranges), respectively. The increase in energy savings from Wind Technologies and Solar Technologies is partially because of the nature of linear programming for it enables renewable energy resources to capture the entire available market in a given region, and after 2010 these technologies have the lowest levelized costs of energy in some regions of the country.

Table 1-6. Primary Energy Savings by OUT Planning Units
(Quadrillion Btu)

	2000		2010		2020	
	Intgtd. Results[7]	Sector Results	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results
Biomass Technologies	.21-.5	.03	.21-.4	.45	.44-.5	1.07
Energy Storage		.01		.08		.5
Geothermal Technologies	.16-.5	.15	.41-.7	1.47	.98-1.8	2.89
High Temp Supercondctvty		.01		.31		.69
Integrated Resource Plng	.16	.36	.30	.86	.34-.4	.59
Solar Technologies	.01-.06	.03	.02-.9	.14	.78-1.6	.45
Transmission & Distribtn	.07	.00	.05-.1	.19	.06-1.0	.38
Wind Technologies	.02-.24	.18	.13-.4	.41	.84	.8

[6]As noted in Footnote #2, a range is presented for the OUT integrated results because we ran the integrated model with and without the OBT and OIT program energy demand impacts. The first digit in the range includes the OBT and OIT program energy demand impacts, while the second digit in the ranges excludes those demand impacts. As OBT and OIT planning units met their goals and objectives of increasing energy efficiency, total energy demand was decreased, thereby reducing the need for generation capacity. This in turn reduced the impact of the OUT programs on energy efficiency. The range thus enables the reader to see what impact OUT's programs will have on energy savings if OBT and OIT's planning units meet all their goals and objectives as well as if OBT and OIT's planning units partially meet their goals and objective.

[7]The OUT integrated results do not include the impacts of energy storage and high temperature superconductivity programs due to modeling limitations.

CONCLUSION

The integrated model analysis indicates that EE's programs will have a positive effect on energy efficiency and emissions (see Table 1-7). In relation to energy efficiency, we estimate that total primary energy savings resulting from the EE programs will increase by approximately 500 percent in the 20 year period from 2000 to 2020, growing from 3.2 quads to 19.2 quads, respectively. Environmentally, the energy savings will help remove approximately 56 MMTC from the environment in the year 2000, increasing to 406 MMTC in the year 2020. This will be a significant contribution to the administration's Climate Change Action Plan and EE's R&D program. In conclusion, these findings indicate that EE's programs will have a beneficial impact on energy efficiency and emissions in United States.

Table 1-7. Summary Integrated Model Results

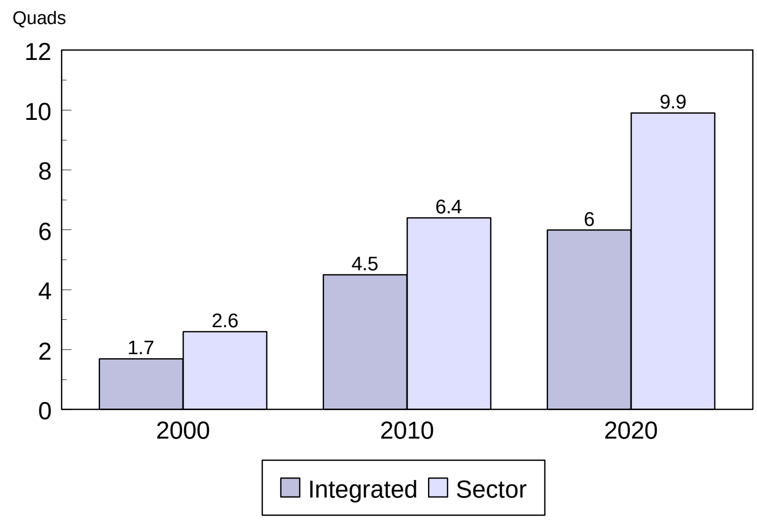
Year	Energy Savings (quads)	Carbon Emissions Reductions (MMTC)
2000	3.2	56
2010	10.4	212
2020	19.2	406

BENEFITS OF OBT PROGRAMS

SUMMARY OF RESULTS

The integrated modeling results for the buildings sector project significant energy savings due to the Office of Building Technology (OBT) programs. The large savings are projected to result from improvements in building shell integrity, heating and cooling equipment, and appliances. However, the projected savings from the integrated model are lower than the OBT estimates, and the difference increases over time. For example, the OBT estimated savings are 2.6 quads for 2000, while IDEAS estimates are 1.7 quads. By 2020 the comparison is 9.9 quads for OBT and 6.0 quads for IDEAS (see Figure 1).

Figure 2-1. Primary Energy Use Benefits of OBT Programs by Integrated Results and Sector Results



There are several reasons for the differences between the estimates, including various interactive effects, optimistic program assumptions, estimates of market penetrations of new technologies, and other modeling constraints. Some program components were not modeled because it was not possible to reasonably represent them using the IDEAS model structure. Another modeling constraint is when a new technology is determined by the IDEAS model to be cost-effective, it gains significant market share immediately because of the model's structure. In reality, new technology market penetrations tend be more gradual (comparable to an "s-shaped" curve) and occur over several years. Some adjustments were made in IDEAS to reflect a more gradual adoption of new technologies, but this structural issue may partially explain why IDEAS results are closest to OBT estimates in the year 2000. Although in the post-2010 period the market share of new technologies does not increase, the share in the total stock continues to increase as new purchases are made.

When OBT programs are integrated with other sector programs in the Full-EE Case, estimated savings are reduced by 9 to 20 percent. As demand for energy is reduced, energy prices drop and savings expected from OBT programs are reduced as consumers react to these lowered prices and use more energy. Several other interactive effects discovered through this integrated modeling process are discussed in the *Issues* section.

Figure 2-2 provides a comparison for a set of planning units of OBT estimated impacts with the IDEAS model results for non-renewable energy savings in the year 2010. IDEAS results for planning unit groups are from cases in which each group is run individually. The total of the savings by group does not equal the sector total described above due to the interactive effects of combining all the EE sector programs together. Because of overlaps in model parameters used and time constraints, the planning units were not evaluated individually and were placed into groups (see Table 2-1 for additional information). This figure indicates that the Building Standards/Systems R&D, and the Lighting and Appliance Standards/R&D planning unit groups have the largest impact. These groups are still not exactly the same as the aggregations of the OBT planning units. For example, in IDEAS the Building Envelope and Heating/Cooling Equipment R&D planning unit group only includes the R&D measures and does not include the impact of two Climate Change Action Plan (CCAP) initiatives that were included by OBT. Instead, the Actions (the Heating/Cooling component of CCAP #6: Residential Market-Pull Partnerships and CCAP #4: Commercial Demonstrations) were included in the Building Standards, etc. Group with the other CCAP actions affecting heating and cooling. The CCAP items were kept in the same groups in the IDEAS model because that is how they were modeled for the Plan last year. No new input assumptions were provided for the Quality Metrics analysis, so the same assumptions were used as last year.

Figure 2-2. Estimates of OBT Program Impacts, 2010

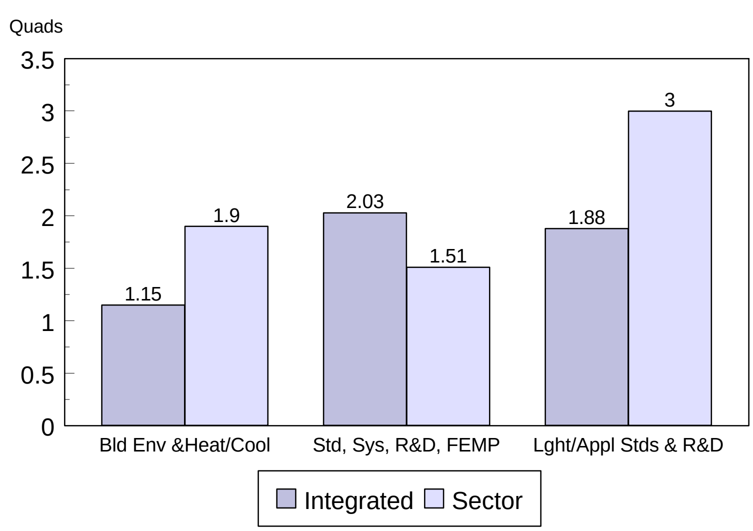
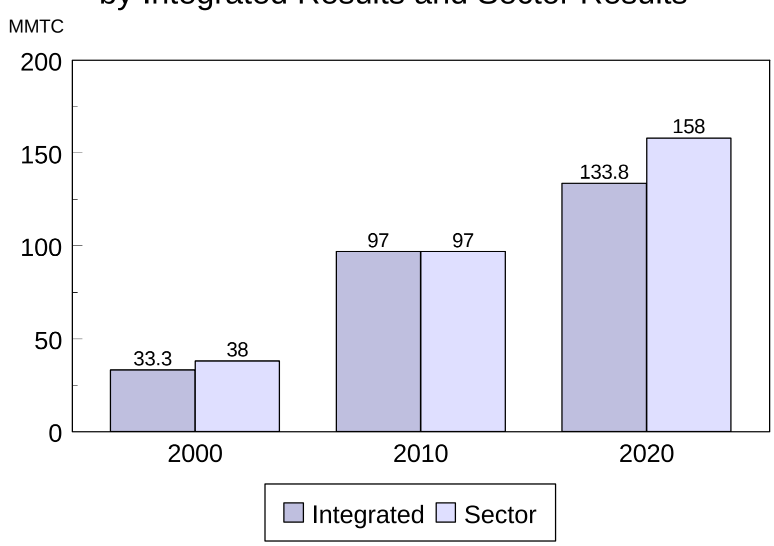


Table 2-1. Primary Energy Savings by OBT Planning Units (Quadrillion Btu)						
	2000		**2010**		**2020**	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
Building Env R&D	.07	.04	1.15	.4	1.81	1.03
Heating/Cooling Eqpt R&D		.71		1.5		2.63
Building Standards	.94	.24	2.03	.52	2.67	.87
Building Systems R&D		.28		.65		1.15
FEMP		.13		.19		.19
Implmtn & Deploymnt		.14		.15		.15
Lighting /Appliances Stds	.781	.96	1.88	2.43	2.67	2.71
Lighting /Appliances R&D		.04		.57		1.13

Carbon emission savings are shown in Figure 2-3. The IDEAS projections of carbon savings are based on direct energy savings in buildings and carbon savings associated with the electricity demand reductions. The IDEAS carbon savings are proportionally higher than the OBT estimates. For

Figure 2-3. Carbon Emission Benefits of OBT Programs by Integrated Results and Sector Results



example, in the year 2000 the IDEAS model estimates that carbon emissions are reduced by roughly 20 MMTC for each quad of primary non-renewable energy saved. The OBT estimate is roughly 15 MMTC/quad. Because the lowest carbon intensive fuel is natural gas with a factor of roughly 14.4 MMTC/quad, the OBT estimate implies that almost all the savings are due to reductions in natural gas consumption, either in direct use or in electricity production. In IDEAS the energy savings include natural gas and oil direct consumption and gas, oil and coal savings from electricity reductions. One of the benefits of using an integrated model is that the carbon savings associated with electricity demand reductions are endogenously calculated. The probable reason for the difference is that in the sector estimates an average factor for the mix of energy from AEO was used and in the integrated case the mix was different.

METHOD OF ANALYSIS

The first part of the Quality Metrics integrated modeling process was to develop a projection of energy consumption through the year 2020 which included no effects from OBT programs. This baseline was developed from EIA’s 1994 Annual Energy Outlook (AEO94) by removing any assumptions that EIA made concerning EE programs. The baseline is called the No-EE Case. The case in which all the program offices' planning units were modeled was called the Full-EE Case. Energy savings estimates are calculated by comparing energy consumption in both cases.

The program offices provided data and documentation for their programs. OBT grouped the programs into eight planning units:

- Heating and Cooling Equipment R&D
- Building Envelope R&D
- Building Systems R&D
- Building Standards
- Lighting and Appliance Standards
- Lighting and Appliance R&D
- Federal Energy Management Program
- Implementation and Deployment

Each planning unit has one or more components, or specific programs. For example, the advanced electric heat pump is a component within the equipment R&D planning unit. OBT provided descriptions and data for most components and planning units.

The IDEAS integrated modeling process consisted of evaluating the data and description of each component and determining the best way of representing the program within IDEAS. Table 2-2 provides a list of each OBT component with the type of modeling methodology used to represent it in IDEAS. Those components listed as "not included" were not modeled either because insufficient data were provided or because their structure could not be reasonably represented in IDEAS.

Table 2-2. Methodologies Used to Model OBT Programs						
Planning Unit	Description	Technology Specification	Minimum Efficiency Set	Exogenously Specified Penetration	Various Parameters	Not Included
Office of Building Technologies						
Residential Systems	Passive Solar Design				X	
	Building America					X
	CCAP Action #11: Energy Value Homes				X	
Residential Equipment	Advanced Electric Heat Pump	X				
	Improved Oil Furnaces	X				
	Natural Gas Heat Pump			X		
	Super Efficient Refrigerator	X				
	Solar Water Heating	X				
	CCAP Action #6: Rebuild America				X	
Commercial Systems	Advanced Building Automation	X				
	Passive Solar Design				X	
	CCAP Action #1: Rebuild America				X	
Commercial Equipment	Advanced Electric Heat Pump	X				
	Improved Oil Furnaces	X				
	Advanced Lighting Systems Replacing Fluorescent Lighting	X				
	Advanced Lighting Systems Replacing Incandescent Lighting	X				
	Gas Heat Pump			X		
	Solar Water Heating	X				
	Gas Chiller			X		
	CCAP Action #4: Cost-Shared Demonstrations of Emerging Technologies				X	

Table 2-2. Methodologies Used to Model OBT Programs (cont'd)						
Planning Unit	Description	Technology Specification	Efficiency Set	Specified Penetration	Various Parameters	Not Included
Office of Building Technologies						
Building Envelope	Adv. Windows–Residential	X				
	Red. Env. Leakage–Residential	X				
	Insulat. Walls/Roofs–Residential	X				
	Advanced Windows–Commercial	X				
	Red. Env. Leakage–Commercial	X				
	Insulat. Walls/Roofs–Commercial	X				
Appliance Standards	Appliance Standards for 7 Residential Products (water heaters, room Acs, ranges, ovens)		X			
	Standards for fluorescent lamp ballasts		X			
Building Standards	CCAP Action #10: Upgrade Residential Codes		X			
	CCAP Action #10: Upgrade Commercial Codes					X
FEMP	Achieve objectives of Executive Order 12902					X
Implementatio n and Deployment	Outreach Networks/Information Dissemination					X
	CCAP Action #5: Energy Efficiency & Renewable Energy Training Programs				X	
	CCAP Action #9: Cool Communities					X

Technology specification refers to using the technology characteristics of a specific program or component and including them in the appropriate IDEAS conservation cost curve. Because the cost curves incorporate both the cost and energy savings for a technology, this modeling technique allows each technology to compete for market share. Thus, the projected market penetrations for the new technologies are not necessarily the same as projected by OBT.

Appliance and building code standards were modeled by setting minimum efficiencies. These efficiencies were set to begin in 1993 for EPAct standards and in 1998 for the proposed appliance standards. As new buildings and/or appliances are purchased after these years, the model forces new stock additions to have at least these efficiencies.

In several instances the IDEAS model had no current technology competition data for a planning unit, when this occurred it was necessary to specify market penetration rates exogenously. Examples of these technologies include gas heat pumps and gas chillers. For these technologies, the penetration rates were specified exogenously using data provided by OBT. The buildings sector also provided data used to set each technology's projected efficiency. The heating and cooling service demands met by the OBT technology are calculated and removed from the rest of the service demand, which will be met by other fuels and technologies.

Components modeled using "various parameters" include primarily Climate Change Action Plan (CCAP) actions (see Table 2-2).. For this analysis, CCAP savings were applied on top of the other Quality Metrics planning units and components. Model parameters used to represent the actions include reducing consumer hurdle rates, increasing the rate of retrofit investments, and/or setting minimum standards.

ASSUMPTIONS FOR ANALYSIS

No-EE Case

The No-EE Case was developed from an IDEAS base case calibrated to the AEO 1994 forecast. The policies included in this projection that were determined to be attributable to OBT programs were removed -- essentially EPAct standards and the proposed 1998 appliance standards. These standards/codes were:

Residential--EPAct Standards/labeling:

- Window labeling
- Low flow showerheads

Residential-- 1998 Standards:

- Water heaters-- gas and electric
- Cooking-- gas and electric

- Refrigerators (reflects effects of the utility collaborative program to produce an ultrahigh efficiency refrigerator)
- Residential room air-conditioners

Commercial--EPAct Standards/Labeling:

- HVAC Standards-- gas-fired forced-air furnaces, unit electric air conditioners, electric air heat pumps, electric water heaters, gas water heaters, and oil water heaters
- Lighting-- fluorescent lamps and incandescent reflector lamps

Commercial--1998 Standards:

- Central air conditioning heat pumps
- Fluorescent reflector lamps

As a result of the removal of these standards and codes, the No-EE Case has slightly higher energy consumption than the 1994 AEO. The policies were then included again as EE programs in the Full-EE Case. Although the policies were removed from the case based on assumptions provided by EIA on how they had been implemented in the AEO, the same assumptions were not necessarily used for the planning units. For example, the 1994 AEO did not include the heat pump water heater as part of the proposed standard, but it is included in the OBT planning units.

Full-EE Case

After developing the No-EE Case, each OBT planning unit and its components were modeled using the assumptions provided by OBT. Assumptions not provided by OBT were taken from other sources. Assumptions used for CCAP components were developed during the October 1993 CCAP modeling process. Most of the building sector CCAP actions were based on assumed penetration rates (percent of homes or floorspace affected) and percent savings by end-use affected. The *CCAP Technical Annex* provides a summary of these assumptions. EPAct standards were modeled based upon the legislation. The 1998 appliance standards were modeled using data compiled for the proposed rules found in "Technical Support Document; Energy Efficiency Standards," November 1993.

ISSUES

Integrated modeling of the OBT programs raised several significant issues. Perhaps the most important is that interactions can and do occur among the planning units. One interactive effect is that the savings from one technology are reduced when implemented with other energy efficiency improving technologies. This occurs, for example, when heat pumps and envelope measures, such as advanced windows, are both installed in the same house.

One of the "metrics" for the QM process is non-renewable primary energy consumption reduction. Because OBT programs reduce overall demand for electricity, the market for high-efficiency/renewable generation options is reduced. Conversely, the introduction of high-efficiency/renewable generation options also reduces non-renewable energy savings associated with buildings electricity demand reductions. By using an integrated model, the primary electricity savings can be calculated in an internally consistent way.

The non-renewable energy savings projected by IDEAS for electricity demand reductions in buildings are considerably smaller than those estimated by OBT. This is partially due to accounting difference of whether renewable inputs to electricity generation are included. In IDEAS the effective heat rate for power generation excluding renewables is roughly 9,200 MMBtu/kwh in IDEAS (although it varies by year). The QM team used an estimate of 10,900 (3.2 times the delivered quads) taken from AEO94. As a result, the IDEAS savings due to electricity demand reductions are almost 20 percent lower. For the comparison of planning unit groups shown in Figure 2-2 and Table 2-1, the IDEAS electricity reductions were converted to non-renewable energy savings using the 3.2 factor in order to provide a consistent comparison with OBT estimates.

Another interactive effect is when demand reductions lead to lower energy prices, which can mitigate program impacts. Energy prices are 2 to 6 percent lower in the Full-EE Case than in the No-EE Case. Although the impacts of price changes in the Full-EE Case are relatively small in terms of total energy consumption, the change in demand proportionately reduces the savings by a larger amount (because the savings are the difference between the No-EE Case and the Full-EE Case). Combined, these three interactive effects reduce OBT savings by 20 percent in the year 2020 relative to a case where OBT programs are analyzed in isolation.

Carbon emissions associated with electricity generation and consumption can also be affected by interactive effects. The magnitude of carbon emission reductions achieved by OBT programs is, in part, determined by the utility operation mix. Although OBT programs are reducing buildings electricity consumption, OUT programs are increasing the use of renewable fuels for electricity generation. Since renewable electricity generation produces no carbon emissions, carbon emissions per kilowatt-hour of electricity consumed are lower.

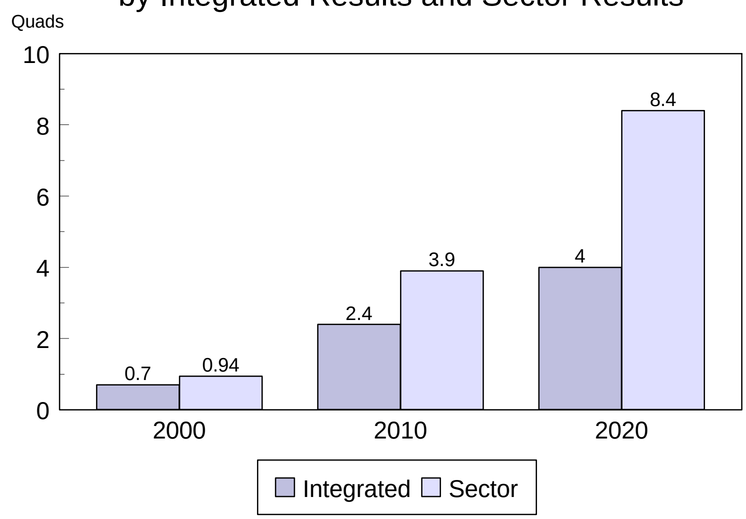
Some planning units components appear very similar to CCAP building sector actions. For example, CCAP action #11, Energy Value Homes, was created to encourage homebuilders to build energy-efficient new homes. According to CCAP documentation, a primary focus of this action is to increase the use of active and passive solar technologies. This CCAP action appears identical to another Building Systems R&D planning unit component, passive solar design, which is intended to increase use of passive solar techniques in new homes. These overlaps indicate there may be some "double-counting" of energy savings attributed to OBT programs.

BENEFITS OF OIT PROGRAMS

SUMMARY OF RESULTS

The integrated model estimates that energy savings due to OIT planning units will increase by approximately 500 percent in the 20 year period from the year 2000 to 2020. OIT estimates that energy savings from OIT programs will reach 8.4 quads in 2020 (see Figure 3-1). The planning units that contribute the largest savings are Industrial Wastes, Cogeneration, and Solar Industrial

Figure 3-1. Primary Energy Use Benefits of OIT Programs by Integrated Results and Sector Results

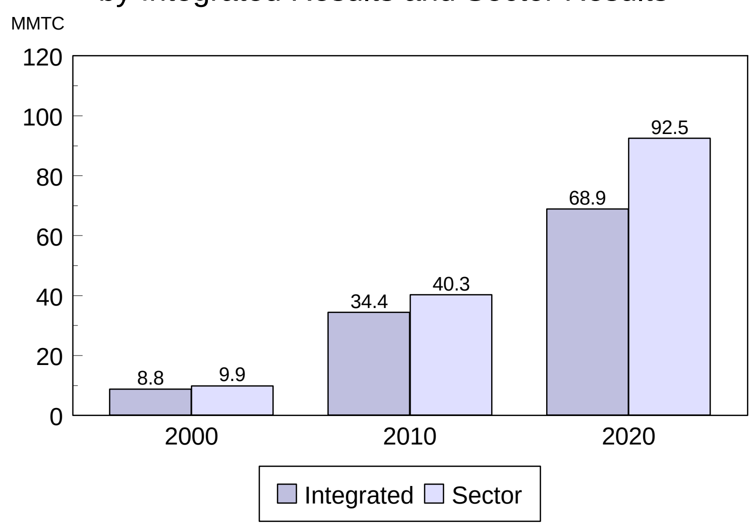


Applications (see Table 3-1). The difference between the estimated savings produced by the integrated model and OIT is significant in 2010 and 2020. To the extent possible the same basic assumptions were used, even in most cases the same market penetrations. For most of the planning units, the disparity in estimates seems to stem from different target market projections, interpretation of assumptions, treatment of vintaging, and interactive effects. However, for a few of the planning units, the technologies could not be fully modeled. These included the non-industrial impacts of solar applications and motors. These segments were not included in the integrated modeling due to concerns of overlapping impacts with programs of other offices. For example, both OIT and OBT have solar programs. It is not clear whether these programs are targeting the same markets, and how benefits from additional solar use would be allocated to the two sectors.

Table 3-1. Primary Energy Savings by OIT Planning Units (Quadrillion Btu)						
	2000		2010		2020	
	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results
Chemicals & Petroleum	.0012	.008	.02	.04	.04	.07
Cogen [8]	.07	.02	.15	.17	.45	.54
Electric Motors[9]	.04	.07	.12	.34	.24	..37
Implment & Deploymnt	.007	.02	.01	.02	.02	.02
Industrial Wastes	.29	.39	1.12	1.82	2.07	3.58
Metals & Materials	.04	.05	.32	.44	1.21	1.50
Municipal Solid Waste	.3	.34	.6	.66	.7	.98
Process Htg & Cooling	.01	.03	.08	.22	.12	.3
Pulp & Paper	.001	.002	.01	.02	.02	.03
Solar Industrial Applns	.005	.007	.12	.17	.70	1.01

The carbon savings associated with the program energy savings are shown in Figure 3-2. The IDEAS estimates increase from approximately 9 MMTC in 2000 to 69 MMTC by 2020. Again, these are lower than the OIT estimates. The carbon savings are proportionally higher in IDEAS, mostly due to a difference in the mix of fossil fuel savings.

Figure 3-2. Carbon Emission Benefits of OIT Programs by Integrated Results and Sector Results



[8] Applied at 1/3 attribution rate to OIT.

[9] Applied at 20% attribution rate to OIT.

METHOD OF ANALYSIS

The integrated analysis involved 10 OIT planning units:

- Pulp and Paper
- Chemicals and Petroleum Refining
- Electric Motor Systems and Motor Challenge
- Cogeneration and Supporting Materials
- Process Heating and Cooling
- Metals and Materials
- Solar Industrial Applications
- Industrial Waste
- Municipal Solid Waste
- Implementation and Deployment.

In general, OIT's technologies target energy efficiency improvement, waste reduction, and increased use of renewables in the industrial sector. However, OIT has several projects that also benefit other sectors. For example, the Advanced Turbine System (ATS) program, which is under the Cogeneration and Supporting Materials planning unit (hereafter referred to as the Cogeneration planning unit), impacts not only industrial cogenerators but also electric utilities and other cogenerators. The Municipal Solid Waste (MSW) program also targets the electric power producers. The Solar Industrial Process program aims at both industrial and commercial applications. The Neodymium project under the Metals and Materials planning unit aims to improve efficiency of all electric motors including those used in residential and commercial appliances. The Motors and Solar Non-Industrial planning unit components were not modeled. The Cogeneration planning unit and the MSW planning unit were modeled in IDEAS and DEGREES. The following steps were taken to analyze the impact of OIT technologies:

(1) Developed a No-EE Case industrial energy projection using PNL's Industrial Model for Energy Analysis and Forecasting (IMEAF)
(2) Developed a complete No-EE Case using the IDEAS integrated model employing the results from IMEAF's No-EE Case
(3) Developed a No_Cogen Case industrial energy projection using IMEAF. The forecasts from the No_Cogen Case shows the impact of all OIT technologies, except for those included in the cogeneration planning unit, on industrial energy consumption.
(4) Developed a complete Full-EE Case using the IDEAS model employing the results from IMEAF's No_Cogen Case

For this analysis, the energy impact on the industrial sector from OIT technologies (except for technologies included in the Cogeneration and Supporting Materials planning units) were estimated using PNL's Industrial Model for Energy Analysis and Forecasting (IMEAF). The IDEAS model was used to assess the impact of the cogeneration planning unit. The MSW planning unit was analyzed with the OUT planning units using the DEGREES model. The results from the IMEAF and the DEGREES analyses were then incorporated into the IDEAS and integrated Full-EE Case.

Industrial Model for Energy Analysis and Forecasting

The primary model used to estimate the benefits of OIT technologies on the industrial sector was the Industrial Model for Energy Analysis and Forecasting (IMEAF). Pacific Northwest Laboratory (PNL) developed IMEAF to fulfill the need for an industrial model appropriate for integrated analysis of Quality Metrics (QM) results. IMEAF is basically a modified version of the industrial module of EIA's National Energy Modeling System (NEMS). NEMS is the modeling system used by EIA to develop the Annual Energy Outlook projections of energy consumption and prices. The key capabilities of IMEAF are similar to that of the NEMS module:

- It represents over 30 industrial sectors
- It models over 30 fuel types
- It models several major energy service components for each sector (HVAC, lighting, motors, process and assembly, boilers, cogeneration)
- It divides each energy intensive industry's (Food, Paper, Chemicals, Glass, Cement, Steel, Primary Aluminum) process and assembly component into process flows
- It recognizes that the basic drivers of energy consumption are industry output and employment, energy prices, and energy efficiency trends of each energy service of each sector
- Its processes are vintaged
- It models byproduct energy production and consumption
- It calculates energy-based emissions (C, SO_x, NO_x, VOC, CO, CO_2).

The basic modifications performed on the NEMS industrial model to create IMEAF were:

- Modified to run in a PC environment
- Added the petroleum refining industry
- Removed regional capability
- Modified to model only industrial on-site electricity generation
- Added capability to calculate electricity consumption for motors.

After the modifications were performed, the model results were then calibrated to the 1994 Annual Energy Outlook (AEO94).

No-EE Case

To develop the No-EE Case for the industrial sector, OIT projects included in the AEO94 forecast of industrial energy consumption were first identified. The parameters in the model that implicitly involved these technologies were changed appropriately for this scenario's assessment. The results revealed that the industrial energy projection under the No-EE Case did not differ significantly from that of the AEO94.

No_Cogen Case

As previously discussed, some OIT technologies impact sectors other than the industrial sector. The strategy used to implement OIT planning units for these cases was to first assess the impacts on the industrial sector using IMEAF and then assess the impacts on the other sectors using the appropriate other models. However, an exception was recognized for the Cogeneration planning unit. Since IMEAF was only capable of assessing on-site electricity generation, and since IDEAS has a complete representation of the cogeneration market, it was decided that the Cogeneration planning unit would be analyzed (including industrial on-site cogeneration) by IDEAS. Hence, a No_Cogen Case was developed for the industrial sector, which involved the assessment of the impact of all OIT projects, except those included in the Cogeneration planning unit, on industrial energy consumption.

IMEAF is not a technology choice model and so it cannot ascertain the market penetration of OIT technologies. Nevertheless, it provides important details that were essential in defining better target market energy consumption forecasts. It also provides a capability to capture some dynamic relationships between the numerous processes within an industry that would result in a more complete and more detailed assessment of the OIT technologies.
Given IMEAF's strengths and limitations, the methodology used in assessing the impact of OIT projects on industrial sector energy consumption was simple. In general, each project within each planning unit was analyzed and then implemented in IMEAF by changing the No-EE Case's energy efficiency trends of the project's target application. The amount of variation was determined by the market penetration and energy efficiency improvement assumptions given by the program managers. A detailed description of how OIT planning units were implemented in IMEAF for the No_Cogen Case is provided in *Assumptions and Analysis* section below. The resulting industrial energy consumption projection was then passed to the IDEAS model for the Full-EE case assessment.

Full-EE Case

The integrated Full-EE Case was developed from the No_Cogen Case described above. First the industrial sector of IDEAS was calibrated to the IMEAF No_Cogen Case results. The autonomous energy efficiency factors and the motor efficiency parameters in IDEAS were modified to reflect the IMEAF savings for the OIT programs as a group. Because the savings were modeled using model parameters within IDEAS and were not “hard-wired”, the industrial energy consumption in the Full-EE Case is still responsive to changes in energy prices.

The next step in developing the integrated OIT portion of the Full-EE Case was including the Cogeneration planning unit. This planning unit contains two components: cogeneration and utility technologies. The cogeneration technology was included in the industrial sector through increasing the efficiency of gas cogeneration. The utility advanced gas turbine system (ATS) was included in the utility sector by changing the cost and heat rate of the advanced gas combined cycle technology already in the No-EE Case. The OIT technology has a much higher heat rate, and a higher capital cost. Each of these technologies compete with others in their respective markets. From the integrated Full-EE Case, the savings that result from increased cogeneration and the utility use of the ATS are allocated to OIT. The MSW planning unit was represented with the OUT programs in the DEGREES model. The IDEAS utility sector renewables and MSW projections were then calibrated to the DEGREES projections for the No-EE and Full-EE Cases.

ASSUMPTIONS OF ANALYSIS

No-EE Case

To create the No-EE Case energy consumption projection for the industrial sector, OIT technologies included in the Quality Metrics (QM) process and also represented in the AEO94 forecast were initially identified. The OIT technologies identified to be incorporated in the AEO94 industrial forecast were:

- Black liquor use and recovery
- Impulse drying
- Electric motors
- Ferrous scrap preheater
- Direct ironmaking/steelmaking
- TiB2 cathodes

An industrial energy consumption forecast without the above technologies was developed with IMEAF for the No-EE Case. This entailed changing the AEO94 projected energy efficiency trends of the energy services or processes in which these technologies were included. The resulting industrial energy forecast was passed to the IDEAS model for further integrated assessment of the No-EE Case.

Full-EE Case

a. No_Cogen Case

Developing the No_Cogen Case for the industrial sector basically entailed a "bottom-up" approach in which each technology was analyzed and then implemented in IMEAF. For each technology, the pertinent target application in the model, guided by the information given by the program manager, is first identified. The appropriate parameters in the model were then changed to reflect the impact of the technology on the market. The percent change on the parameter was dependent on the energy efficiency improvement and market penetration assumptions given by the program manager. Appendix A presents the assumptions used to implement each OIT project for the No_Cogen Case.

For the OIT technologies that target the same applications, no attempt was made to compete the technologies against each other. The implication of this is that the reduction in energy intensity will decrease based on the application of all the appropriate technologies' market penetration and percent energy efficiency improvement. In some cases the program managers indicated that they adjusted the assumptions when the technologies had the same target applications.

b. Cogen Case

The assumptions for most of the OIT planning units are implicitly the same as those in the No_Cogen Case. The Cogeneration planning unit was modeled in two components. First, the efficiency of industrial gas-fired cogeneration for external sales was increased by twenty percent with no change in cost. Second, OIT advanced gas turbine technology characteristics were improved. The OIT advanced gas turbines are assumed to be available in 1995, contrasted to a 2005 commercialization in the No-EE Case. OIT advanced gas turbine assumptions are compared with the No-EE Case assumptions in Table 3-3 below. The No-EE Case advanced gas turbine assumptions are based on AEO94 advanced gas combined cycle characteristics.

Table 3-3. Comparison of Advanced Gas Turbine Assumptions

	Full-EE Case	**No-EE Case**
Capital Cost (92$/kw)	725	575
Heat Rate (Btu/kWh)	5,975	7,869
O&M Cost (mills/kWh)	5.2	5.2
Commercialization Year	1995	2005

ISSUES

The results from the integrated model include the interactive effects from the other sector programs through energy prices and the mix of generation in electricity supply. For example, the industrial energy prices in 2020 in the Full-EE Case are roughly 5 to 10 percent lower than in the No-EE Case due to reduced energy demand in all sectors. As a result, industrial energy demand is roughly 1 percent higher in the Full-EE Case than it would be without the price change. Consequently, the program impacts, which are measured as the difference between the Full-EE Case and the No-EE Case, are reduced by roughly 0.3 quads by 2010 or 10 percent. The mix of utility technologies impact OIT savings through the primary non-renewable energy savings associated with each kilowatt-hour savings in industry. As more renewables are added to the generating mix, the savings associated with industrial electricity demand reductions are reduced. In addition, as described above, the renewable technologies compete with the advanced gas turbine technology to meet any new growth in electricity demand.

The difference between the No_Cogen Case and the No-EE Case is the energy savings for the industrial sector due to OIT programs. The disparity between this result and OIT's QM estimates of energy savings in the industrial sector is significant in spite of using the same basic assumptions (e.g. market penetration, energy efficiency improvement) as those used for the OIT QM estimates. After a careful examination of the model's capabilities and the procedure used by OIT to calculate its estimates, it is believed that apart from the effects of integrating the impacts of the technologies together, the major bases of this disparity are: (1) the refinement of the target market energy consumption projection; (2) the analyst's interpretation of the program manager's assumptions; (3) the more refined accounting of vintages in the model; and (4) the additional consideration of other energy consuming processes affected by the technology that were taken into account by the model.

The planning units with the biggest difference between OIT's and the model's estimates are Electric Motors, Solar Industrial Applications, and Industrial Waste. Some insights on the reasons for these differences are provided below.

Electric Motors

Without applying the 20 percent attribution rate, OIT's estimates and the integrated model estimates are 1.8 quads and 1.2 quads in 2020, respectively. In OIT's energy savings results for the electric motors planning unit, the program manager provided only ranges of market penetration rates assumed in their estimates. The analyst then had to "best guess" a point market penetration for each forecast year for each industry. It is possible that the analyst underestimated or overestimated the market penetration rates used in the model.

Solar Industrial Applications

OIT's energy savings for its solar program includes both industrial and commercial applications. The model results presented are only from the industrial sector. No assessment was performed on the planning unit's impact on the commercial sector.

Industrial Waste

The model's implementation of this planning unit used the market penetration and energy efficiency improvement data from OIT. These data were then used to increase the energy efficiency trend of the targeted applications. It is surmised that the difference between OIT's estimates and the model results is mainly due to the refinement of the target applications in the model.

APPENDIX A. OIT PLANNING UNIT IMPLEMENTATION FOR THE NO COGEN CASE

Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
PULP AND PAPER			
Impulse Drying	Drying process for Linerboard and Corrugated Medium (68 out of 1150 dryers)	6% (68/1150 dryers) of energy consumption in the papermaking process step in the Paper industry	Energy efficiency trend of papermaking process is changed by the result of multiplying the given market penetration and efficiency improvement. Change applied to all vintage stocks.
Black Liquor Use and Recovery	Recovery boilers	Recovery boilers in Paper industry	Boiler efficiency is changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
CHEMICALS AND PETROLEUM REFINING			
Alternative Feedstocks Program; Biotechnologies for the Chemical Industry	Petrochemical feedstocks consumption	Feedstocks consumed in Bulk Chemical Industry (displaced by renewables)	Energy efficiency trend of feedstocks use is changed by the result of multiplying the given market penetration and efficiency improvement. Increase renewables consumption at a rate of 80% of displaced by program. Change is applied to new vintage only.
Membrane Technologies for the Petrochemical Industry; Sensors and Controls	Distillation	Steam consumption in process and assembly component of the Bulk and Other Chemical Industries, and Petroleum Refining	Energy efficiency trend of steam use in industries mentioned is changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
Catalysis by Design	Petrochemical feedstocks consumption	Feedstocks consumed in Bulk Chemical Industry	Energy efficiency trend of feedstocks use is changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
SOLAR INDUSTRIAL APPLICATIONS The total energy savings from the solar industrial process program had to be estimated using IMEAF and the commercial sector modules of each of the integrated models. The approach described here pertains only to that used in IMEAF.			
Solar Detoxification	The main goal of this OIT program is the mitigation of industrial hazardous waste. Energy savings is minimal.	Not implemented	Not implemented
Solar Industrial Process	Industrial and commercial process heating	Total industrial steam and process heat demand	Total steam and process heat demand by each industry is reduced by the result of multiplying the given market penetration and energy efficiency improvement.

Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
ELECTRIC MOTOR SYSTEMS AND MOTOR CHALLENGE			
Electric Motors System R&D; Motor Challenge; Electric Motor System Golden Carrot	Industrial motors	Electricity consumed for all industrial electric motors	Efficiency trends of electricity use for motors are changed by the result of multiplying market penetration (3.3%, 17.7%, 32.0%, 46.3%, 60.7%, 75.0%) and efficiency improvement (20%). These percentages are just the analyst's guesses based on the ranges of values given by program manager. Change is applied to all vintage stocks.
INDUSTRIAL WASTE			
Supercritical CO_2 Parts Cleaning	Precision parts cleaning: electricity consumption of SIC 37	Electricity consumption for process and assembly of SIC 37	Energy efficiency trend of electricity consumed for process and assembly of SIC 37 is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks
Amine Scrubbing	Natural Gas processing plant	Total natural gas lease and plant consumption.	Energy efficiency trend of natural gas lease and plant is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Superior Asphalt Recycling	Asphalt consumption	Asphalt and road oil consumption in construction industry.	Energy efficiency trend of asphalt and road oil in construction industry is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Tire Recycling	Polymer materials	Natural gas feedstocks and 70% of oil feedstocks consumed in bulk chemicals industry.	Energy efficiency trends of the 70% of oil and 100% gas feedstocks in bulk chemical industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Biological Conversion of Waste Gases to Acetic Acid	Coke and carbon black manufacturing and acetic acid production (SIC 28)	10% of direct gas use, 100% direct coal use, 23% electricity use in bulk chemicals industry	Energy efficiency trends of the given fuels in the process and assembly component of the bulk chemical industry are changed by the result of multiplying the given percentages, the market penetration and energy efficiency improvement. Change is applied to all vintages.
Inorganic Membranes	Petrochemical industry	38% of direct gas use, 2.3% of electricity use in bulk chemicals industry	Energy efficiency trend of the given fuels in the process and assembly component of the bulk chemical industry are changed by the result of multiplying the given percentages, market penetration, and energy efficiency improvement. Changes is applied to all vintages.
Food Waste to Lactic Acid	Production of lactic acid and lactic-derived polymers and chemicals	10% of petrochemical feedstocks and 14% of gas feedstocks in bulk chemical industry	Energy efficiency trend of the given fuels in the process and assembly component of the bulk chemical industry are changed by the result of multiplying the given percentages, market penetration, and energy efficiency improvement. Changes is applied to all vintages.

Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
PROCESS HEATING AND COOLING			
Ferrous Scrap Preheater	Carbon stainless steel	Energy consumed by electric arc furnaces of the iron and steel industry	Energy efficiency trend of the EAF process in the iron and steel industry is changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
Oxyfuel Glass Melting	Glass melting	Energy consumed for the melting process in the glass industry	Energy efficiency trends of melting processes in the glass industry are changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
Advanced Radiant Combustion System	Petrochemical heaters	A portion of the process heating demand in the petroleum refining and bulk chemical industries	Energy efficiency trends of a portion of process heating steps in the refining and bulk chemical industries are changed by the result of multiplying the given market penetration and efficiency improvement. Changed is applied to all vintage stocks.
Work Piece Analyzer	Sensors for optimization of aluminum and steel strip thermal processing	A portion of the gas consumption for process heating in aluminum and iron and steel industries	Energy efficiency trends of a portion of process heating steps in the aluminum and iron and steel industries are changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
HiPHES for Methane Reforming	Natural gas feedstocks	Natural gas feedstocks consumption of Bulk chemicals industry	Energy efficiency trend of natural gas feedstock consumption in the bulk chemical industry is changed by the result of multiplying the given market penetration and efficiency improvement. Change is applied to all vintage stocks.
HiPHES for Remote Industries' Cogeneration	Cogeneration for remote industries	Byproduct energy use for cogeneration in lumber and forestry industries	Increase rate of production of useful byproduct energy in the lumber and forestry industries by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
PERF	The main goal of this program is the mitigation of toxic emissions from petroleum refineries. Energy savings is minimal.	Not implemented	Not implemented

Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
METALS AND MATERIALS The total energy savings for the neodymium metal project had to be estimated with the buildings modules of each of the integrated models. The approach described here pertains only to that used in IMEAF.			
Spray Forming of Aluminum	Metals fabrication	14% of electricity consumption in the primary aluminum industry	Energy efficiency trend of a portion of the primary aluminum process is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to new vintage only.
Metals Casting	Foundries and metals casting	Energy consumption in the casting processes in iron and steel industry	Energy efficiency trends of casting processes in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to new vintage stocks only.
High Performance Insulating Refractory Fibers	Heat loss in heat treating furnaces	Energy consumption in the casting and rolling processes in the iron and steel industry	Energy efficiency trends of the casting and rolling processes in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
High Pressure Aluminum Calciner	Bayer alumina plants	70% of natural gas demand in the other primary metals industry (in the model, alumina plants are included in this industry group)	Energy efficiency trend of a portion of natural gas consumption in other primary metals industry is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Inert Anodes for Magnesium	Primary electrolytic magnesium production	35% of electricity and oil use in the other primary metals industry (in the model, magnesium production is included in this industry group)	Energy efficiency trends of a portion of electricity and oil consumption are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
TiB2 Cathodes	Primary aluminum	Electricity demand in the primary aluminum industry	Energy efficiency trend of electricity for primary aluminum smelting process is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Low Temperature Bath and Pilot Cell	Primary aluminum	Electricity and oil demand in the primary aluminum industry	Energy efficiency trends of electricity and oil for primary aluminum smelting process are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to new vintage stocks only.
Alumina Aggregate	Sidewall heat loss in glass and metal melting and holding furnaces; lime and cement kilns, Tomlison boilers	Energy consumption in glass melting and in cement kilns	Energy efficiency trends for glass melting process and cement kilns are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.

Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
Direct Ironmaking/Steelmaking	Crude steel production	Energy consumption in steelmaking and ironmaking processes of the iron and steel industry	Energy efficiency trends for steelmaking and ironmaking processes in iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Integrated Manufacturing Information System	Flat rolled steel production	0.07% of energy consumption in continuous casting, rolling, blast furnace and basic oxygen furnace processes in iron and steel industry	Energy efficiency trends for the various processes mentioned in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Composites	Metal machining	Electricity consumption in primary aluminum smelting in the primary aluminum industry, casting and rolling processes in the iron and steel industry	Energy efficiency trends for the various processes mentioned in the iron and steel, and aluminum industries are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Membranes	Separations	Not implemented. It was deemed that the results for this project were already counted in the chemical and petroleum refining planning unit.	Not implemented.
Microwave Processing	Specialty glass and ceramics	Electricity and natural gas consumption in the stone, clay, glass industries	Energy efficiency trends for electricity and natural gas in the mentioned industries are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to new vintage stocks only.
Intermetallic Alloys	Ferrous metal heat treating; steel reheat	Energy consumption for casting and rolling processes in iron and steel industry	Energy efficiency trends for the casting and rolling processes in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Electrolysis of Neodymium Oxide	NdFeB magnets for electric motors; will target all motors	Electricity consumption of industrial motors	Energy efficiency trend of electricity use for motors is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Rapid Analysis of Molten Metal	Molten blast furnace/BOF steel product	Energy consumption for blast furnace and BOF processes in iron and steel industry	Energy efficiency trends of BF and BOF processes in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Rapid Glass Refiner	Container glass production	Energy consumption for glass melting and forming processes	Energy efficiency trends of melting and forming processes in the glass industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.

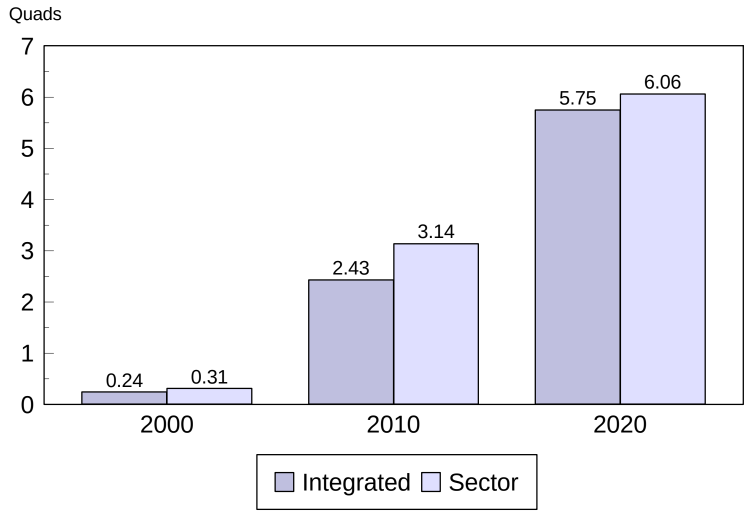
Planning Unit/Technology	Given Target Market	Target Application in IMEAF	Implementation in IMEAF
Waste Oxide Recycling	Iron and steel production	Energy consumption in blast furnace, coke ovens in iron and steel industry	Energy efficiency trends of BF and coke oven processes in the iron and steel industry are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
Advanced Process Control	Production of BOF steel product	Energy consumption in BOF process in iron and steel industry	Energy efficiency trend of process in the iron and steel industry is changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.
IMPLEMENTATION AND DEPLOYMENT			
EADC; EPACT Implementation	Small and medium sized industrial plants	A portion of energy consumption in small to medium-sized plants	Energy efficiency trends in small- to medium-sized industries are changed by the result of multiplying the given market penetration and energy efficiency improvement. Change is applied to all vintage stocks.

BENEFITS OF OTT PROGRAMS

SUMMARY OF RESULTS

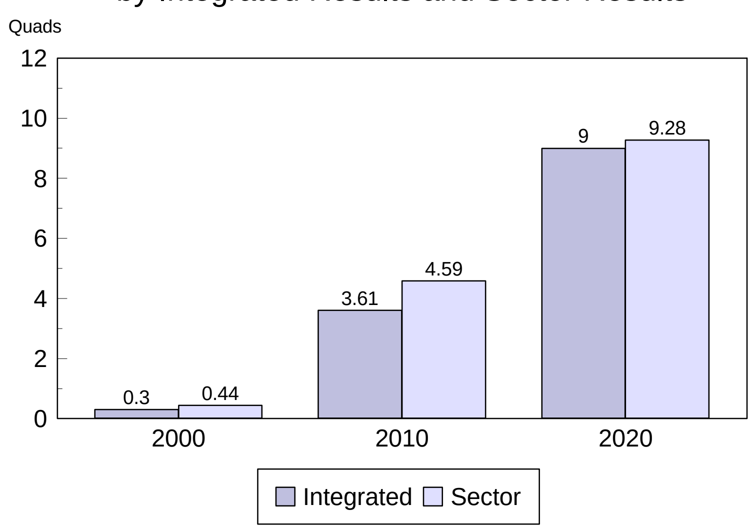
The integrated modeling results generated by IDEAS show significant energy savings for the OTT programs (see Figure 4-1). OTT programs in the Full-EE Case are projected to yield roughly 2.4

Figure 4-1. Energy Savings Benefits of OIT Programs by Integrated Results and Sector Results



nonrenewable energy savings in 2010 with respect to the No-EE base case. This figure increases to 5.8 quads by 2020. In general, the primary nonrenewable energy savings are less than the direct oil savings presented in Figure 4-2 due to fuel switching away from oil toward nonrenewable fuels such as natural gas, methanol (assumes natural gas as the feedstock) and electricity (produced using nonrenewable inputs). Only those direct oil savings generated through higher gasoline and diesel vehicle efficiencies or fuel switching to ethanol, a renewable fuel, contribute to primary nonrenewable energy savings.

Figure 4-2. Direct Oil Savings Benefits of OTT Programs by Integrated Results and Sector Results



As shown in Figure 4-2, direct oil savings generated in IDEAS correspond fairly well to OTT's estimates, although they are somewhat lower. In 2010, the difference stems primarily from slower penetration of materials R&D in IDEAS for conventional light duty vehicles. However, there are also interactive effects taking place within IDEAS due to the substantially higher average fleet efficiencies assumed in the Full-EE program case as compared to the No-EE reference case. Higher efficiencies tend to lower vehicle operating costs and lead to an increase in the demand for travel. This "take back" effect is relatively small in 2010 but becomes more and more significant as the vehicle stock continues to turnover.

Since many of the planning units represent competing technologies, it was not possible to isolate their impacts by running them individually. Consequently, to determine the contribution of each OTT program to total transportation sector savings, it was necessary to take the integrated results from IDEAS for the Full-EE Case and allocate the savings to the individual technologies. This is consistent with the manner in which OTT derived their planning unit estimates.

Table 4-1 presents primary nonrenewable energy savings broken out by planning unit. Nonrenewable energy savings in IDEAS for both the Materials Development and the Biomass Fuels planning units are equal to the direct oil savings shown in Table 4-2. This is true for the Materials Development planning unit because the oil savings generated are due to improvements in conventional gasoline vehicle fuel economy. It is true for the Biomass Fuels planning unit because the oil savings generated are the result of fuel switching away from oil to the renewable fuel ethanol.

Table 4-1. Primary Energy Savings by OTT Planning Units
(Quadrillion Btu)

	2000		2010		2020	
	Intgtd. Results	**Sector Results**	**Intgtd. Results**	**Sector Results**	**Intgtd. Results**	**Sector Results**
AFV Demos	.00	.01	.10	.02	.37	.03
Biomass Fuels	.10	.00	.96	.82	2.11	1.86
Electric Veh Batries/Sstms	.00	-.01	-.01	-.05	-.02	-.06
Fuel Cell Vehicles	.00	.00	.03	.05	.42	.42
Heavy Duty Transport	.02	.04	.26	.50	.54	1.36
Hybrid Vehicles	.00	.00	.18	.24	.75	.74
Implmtn & Outreach	n/m	.06	n/m	.17	n/m	.25
Materials Development	.12	.2	.91	1.39	1.58	1.47

Table 4-2. Direct Oil Savings Due to OTT Programs (Quadrillion Btu)						
	2000		2010		2020	
	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results
AFV Demos	.06	.12	.35	.63	.84	1.23
Biomass Fuels	.10	.00	.95	.82	2.09	1.86
Electric Veh Batries/Sstms	.00	.01	.15	.14	.19	.22
Fuel Cell Vehicles	.00	.00	.05	.09	.78	.63
Heavy Duty Transport	.02	.04	.47	.50	1.21	1.36
Hybrid Vehicles	.00	.00	.74	.83	2.33	2.27
Implmtn & Outreach	n/m	.07	n/m	.19	n/m	.26
Materials Development	.12	.20	.90	1.39	1.56	1.47

In each of the remaining planning units, fuel switching to nonrenewable fuels leads to lower nonrenewable energy savings as compared to direct oil savings. The largest difference is evident in the Hybrid Vehicle planning unit where primary nonrenewable energy savings is projected in IDEAS to be 0.75 quads in 2020, down significantly from the 2.33 quads of oil savings shown in Table 4-2. This is due to the increase in electricity consumption and the need to account for the primary nonrenewable inputs used to generate that electricity.

Heavy Duty Transport technologies also show substantially fewer nonrenewable energy savings than direct oil savings. IDEAS projects nonrenewable energy savings for Heavy Duty Transport to be 0.54 quads by 2020, as compared to 1.21 quads for direct oil savings. This decrease is due to fuel switching away from oil toward nonrenewable fuels such as natural gas, LPG, and methanol. Consistent with OTT estimates, IDEAS projects nonrenewable energy consumption for heavy duty vehicles to increase by as much as 0.62 quads by 2020.

Similarly, nonrenewable energy savings projected in IDEAS for the Fuel Cell Vehicle planning unit are substantially lower than the direct oil savings presented in Table 4-2. OTT assumes that fuel cell vehicles will operate on methanol derived from natural gas, a nonrenewable fuel source. Consequently, the IDEAS results presented in Table 4-1 show 0.42 quads of nonrenewable energy savings as compared to the 0.78 quads of direct oil savings found in Table 4-2. The difference is due to the increase in methanol consumption.

Nonrenewable energy savings projected in IDEAS for the Electric Vehicle planning unit also show a significant decline with respect to the direct oil savings presented in Table 4-2. In fact, the direct oil savings attributed to the Electric Vehicle planning unit is largely offset by the primary nonrenewable inputs used to meet the additional electricity demand.

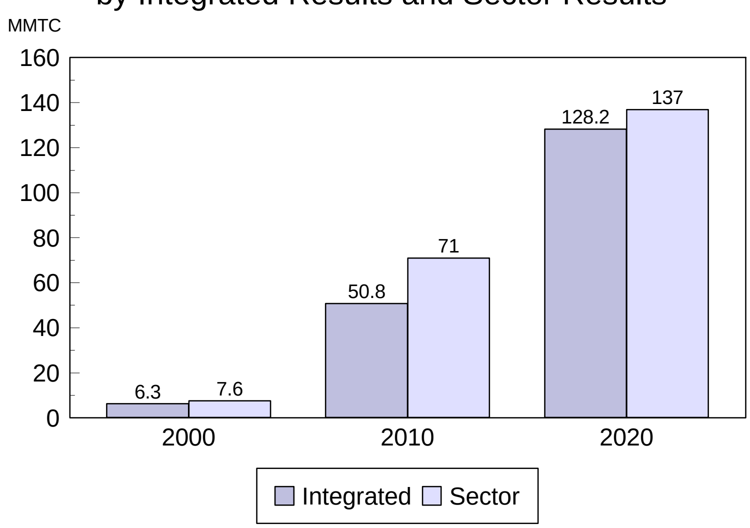
And finally, nonrenewable energy savings in IDEAS for the Alternate Fuel Vehicle planning unit are significantly less than the direct oil savings attributed to it in Table 4-2. This is due to the fact that most of the oil savings results from fuel switching away from oil towards natural gas, a nonrenewable fuel. Only the 0.37 quads of savings due to increased ethanol consumption is included as nonrenewable energy savings in Table 4-1.

As shown in Table 4-1, primary nonrenewable energy savings generated in IDEAS are quite comparable to OTT's estimates, with the one notable exception of the Heavy Duty Transport planning unit. Although IDEAS and OTT show similar direct oil savings for heavy duty transport, IDEAS projects significantly fewer primary nonrenewable energy savings. Consistent with OTT projections, IDEAS assumes that a large part of the direct oil savings is due to fuel switching away from oil toward nonrenewable fuels such as natural gas and methanol. Since these oil savings represent the replacement of one fossil fuel (oil) with another (natural gas), they are not assumed to contribute to primary nonrenewable energy savings in IDEAS.

The reduction of carbon emissions is another "metric" used to evaluate the effectiveness of OTT programs. As shown in Figure 4-3, IDEAS projects significant carbon savings due to implementation of OTT's programs, yielding a net reduction of 128 MMTC of carbon in the Full-EE Case as compared to the baseline in 2020. These savings result primarily from increased efficiencies for conventional and alternate fuel vehicle efficiencies, but fuel switching away from oil to less carbon intensive fuels such as natural gas contributes as well.

The gap between IDEAS results and OTT's estimates is due primarily to the differences outlined above with respect to both the direct oil savings and the nonrenewable primary energy savings.

Figure 4-3. Carbon Emission Benefits of OTT Programs by Integrated Results and Sector Results



METHOD OF ANALYSIS

The integrated analysis included the following eight OTT planning units:

- Alternate Fuel Vehicle (AFV) Demonstrations
- Biomass Fuels
- Electric Vehicle Batteries and Systems
- Fuel Cell Vehicles
- Heavy Duty Transport Technologies
- Hybrid Vehicles
- Implementation and Outreach
- Materials Development

In general, OTT's planning units can be grouped into one of two categories. Those technologies that reduce non-renewable energy consumption by increasing the efficiency of conventional fuel vehicles, and those that reduce non-renewable energy consumption by increasing the penetration of alternate fuel vehicles. The first category includes both Materials Development (conventional light duty vehicles) and Heavy Duty Transport technologies. The second includes AFV demonstrations (compressed natural gas (CNG), liquified petroleum gas (LPG) and ethanol fueled vehicles), Biomass Fuels (lower delivered ethanol price), Electric Vehicle Batteries and Systems, Fuel Cell Vehicles and Hybrid Vehicles. Each of these planning units was modeled in IDEAS using program input assumptions provided by OTT. The Implementation and Outreach planning unit was not included in the IDEAS Quality Metrics (QM) modeling exercise due to the lack of input data and the relatively small energy savings OTT expects it to generate.

The IDEAS integrated modeling process consisted of evaluating the data and description of each planning unit and determining the best way of representing the program within IDEAS. For those programs targeting improved fuel economy for conventional vehicles, advanced technologies were included in the model conservation cost curves in order to generate a higher amount of savings at a given level of investment. In situations where the OTT program targeted increased penetration of alternate fuel technology, vehicle characteristics used to determine consumer buying patterns in the model were adjusted to reflect the appropriate program goals.

ASSUMPTIONS FOR ANALYSIS

No-EE Case

The "No-EE" case for the transportation sector corresponds closely to the IDEAS case calibrated to AEO94. It was decided to use the AEO94 calibration case as a starting point since OTT developed their energy savings estimates by taking credit only for those OTT programs that go above and beyond what is already included in the AEO94. Examples of alternate fuel vehicle legislated programs represented in the AEO94 include both the 1992 Energy Policy Act and the zero-emission vehicle program initiated in California.

Sections 303, 501 and 507 of EPAct require operators of centrally-fueled automobile and light duty truck fleets to purchase a minimum fraction of alternate fuel vehicles starting in 1998. The AEO94 estimates that fleet sales of alternate fuel vehicles will exceed 900,000 by the year 2010, accounting for roughly 5.5 percent of projected light duty vehicle sales.

California's zero emission vehicle program, which has now been adopted by both New York and Massachusetts, requires that 10 percent of all new vehicles sold by the year 2000 meet the "zero emissions requirements." At present, only electric vehicles meet these requirements. Zero Emission Vehicles (ZEV) program sales are expected to account for an additional 2 percent of projected light duty vehicle sales by 2010.

However, despite the fact that mandated sales account for most of the alternate fuel vehicle sales projected in the AEO94, a significant percentage of AFV sales (roughly 20 percent) is still assumed to be market driven.

Full-EE Case

The Full-EE Case was developed by taking the No-EE Case as discussed above and modeling each OTT planning unit individually using input assumptions provided by OTT. These input assumptions represent OTT program goals for each of the various planning units. For those planning units targeting increased penetration of alternate fuel technologies, model inputs included such technology characteristics as capital cost, fuel efficiency, range to refueling, fuel availability, emissions relative to gasoline, and in the case of biomass, the delivered price of ethanol. In the case of materials development and heavy duty transportation, input assumptions represented technical advances in the fuel economy of conventional gasoline and diesel fueled vehicles.

ISSUES

Integrated modeling of the OTT programs raised several important issues with respect to interactive effects within the model. In particular, it emphasized the importance of considering price feedbacks when evaluating program impacts.

One such price effect within the transportation sector is the "take back" effect. This term refers to the fact that higher vehicle efficiencies tend to increase the demand for travel, thereby "taking back" some of the energy savings generated by the efficiency improvement. The increase in travel is a direct result of the fact that as fuel economy improves, consumers see their vehicle operating costs drop (assuming fuel prices do not rise). In the Full-EE Case, average light duty vehicle fleet efficiencies are roughly 32 percent higher than in the No-EE program base case by the year 2020. Coupled with a 10 percent increase in the number of light duty vehicle miles traveled, this equates to a long run elasticity of around 30 percent. Although this elasticity may be a little on the high side (David Greene of Oak Ridge National Laboratory in a recent article published in *The Energy Journal* estimated the take back effect to be in the range of 5 to 15 percent), it is important to understand that increases in consumer demand for travel will lower expected energy savings.

Energy price feedback is also an important feature when considering how the OTT programs interact with programs sponsored by some of the other sector offices. One such example of this is the significant decrease (approximately 4-6 percent) in the delivered price of natural gas seen by the transportation sector due to energy efficiency programs in the residential, commercial and industrial sectors. Lower natural gas fuel prices tend to increase the market penetration of CNG vehicles, resulting in higher than expected direct oil savings attributable to the AFV demonstration planning unit.

Another interactive effect worth considering is the competition for market share among OTT's various technology programs. For example, as the market share for electric hybrid vehicles grows, the potential savings for the ethanol flex vehicle is reduced in part. Similarly, as the market share for alternate fuel technologies grows larger and larger, the potential for energy savings from programs directed at conventional vehicles becomes increasingly smaller. Consequently, both OTT and IDEAS start with the energy savings from the Full-EE Case before allocating them to each of the individual planning unit technologies.

BENEFITS OF OUT PROGRAMS

SUMMARY OF RESULTS

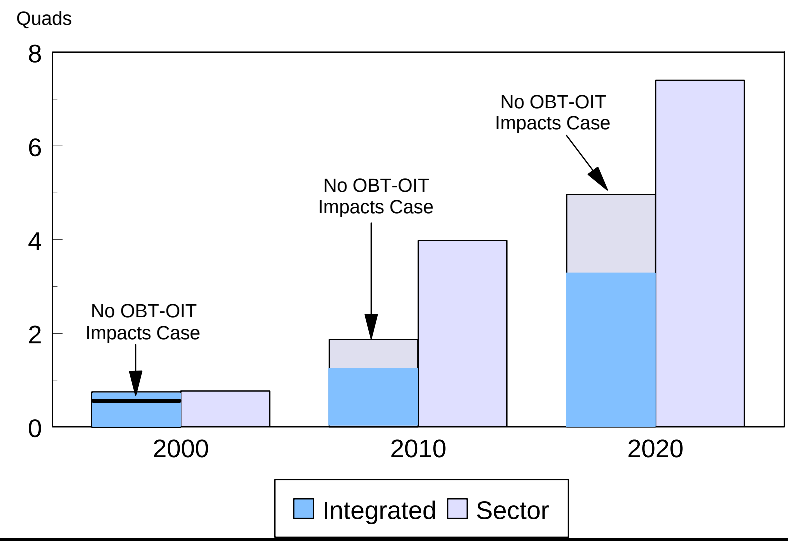
The integrated model estimates that the OUT planning units will save between 0.6 to 0.4 quads of primary energy in the year 2000. A range is presented for the OUT integrated results because we ran the model with and without the OBT and OIT program demand impacts. The first digit of the range includes the OBT and OIT program energy demand impacts (hereafter referred to as the OBT-OIT Impacts Case), while the second digit excludes those demand impacts (hereafter referred to as the No OBT-OIT Impacts Case). Based on the OBT-OIT Impacts Case, the Biomass Technologies planning unit provides the largest energy savings, accounting for approximately a third of the total savings (see Table 5-1). The Integrated Resource Planning and the Geothermal Technologies planning units represent approximately one-half of the total primary energy savings in the year 2000. In the year 2020, we estimate that the Geothermal Technologies planning unit will account for the largest energy savings (based on the OBT-OIT Impacts Case estimate of 0.98 quads), followed by Wind Technologies and Solar Technologies at 0.84 quads and 0.78 quads (OBT-OIT Impacts Case ranges), respectively. The increase in energy savings from Wind Technologies and Solar Technologies is partially due to the nature of linear programming for it enables renewable energy resources to capture the entire available market in a given region, and after 2010 these technologies have the lowest levelized costs of energy in some regions of the country (see the *Method of Analysis* section below for more information about linear programming).

Table 1-6. Primary Energy Savings by OUT Planning Units
(Quadrillion Btu)

	2000		2010		2020	
	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results	Intgtd. Results	Sector Results
Biomass Technologies	.21-.5	.03	.21-.4	.45	.44-.5	1.07
Energy Storage		.01		.08		.5
Geothermal Technologies	.16-.5	.15	.41-.7	1.47	.98-1.8	2.89
High Temp Supercondctvty		.01		.31		.69
Integrated Resource Plng	.16	.36	.30	.86	.34-.4	.59
Solar Technologies	.01-.06	.03	.02-.9	.14	.78-1.6	.45
Transmission & Distribtn	.07	.00	.05-.1	.19	.06-1.0	.38
Wind Technologies	.02-.24	.18	.13-.4	.41	.84	.8

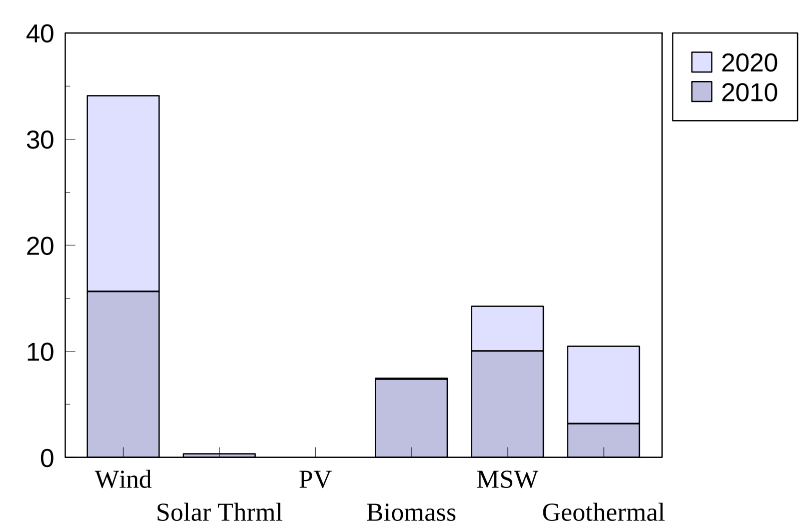
The projected energy savings from the integrated model are lower than the sector model savings (i.e., DEGREES) in the year 2020--3.4 quads to 7.4 quads, respectively (based on OBT-OIT Impacts Case estimate of the integrated results) (see Figure 5-1). There are several reasons for the divergence between OUT's estimates and the integrated model results. First, the integrated model did not represent two of OUT's technologies: superconductivity and energy storage. In 2020, OUT estimates that these technologies will contribute a total of 1.195 quads per year of energy savings. Second, the integrated model estimates are lower than OUT's because the integrated results account for interaction effects with planning units from the other sectors. For example, both OBT and OIT programs, but particularly the former, reduce electricity demand, thereby reducing the market for OUT renewables technologies. (Conversely, OUT renewables programs reduce the average fossil fuel energy required to generate a kilowatt hour of electricity, reducing the primary energy savings attributable to electricity conservation programs in the end-use sectors.) This is further evidenced by the fact that the results of the OUT stand-alone case indicates that renewable electricity capacity will total 206 GW in the year 2020, while the Full-EE Case projected only 151 GW of installed renewable electricity capacity.

Figure 5-1. Primary Energy Use Benefits of OUT Programs by Integrated Results and Sector Results



Regionally, wind generation is very attractive in the Full-EE Case and wind installations are estimated to be present in all NERC regions by the year 2020. Wind is prevalent even in the No-EE Case and it penetrates in most of the same regions as in the Full-EE Case, although in smaller amounts. Interestingly, in the No-EE Case we find that the Wind Technologies planning unit is projected to have the largest renewable electricity capacity in 2010 and 2020 (see Figure 5-2). PV penetration is governed primarily by variations in resource quality. For example, PV penetrates primarily in California and the Southern United States. Geothermal resources penetrate significantly in the West which is the only region they are available. Biomass facilities penetrate in most regions of the country by 2020, but especially along the East Coast.

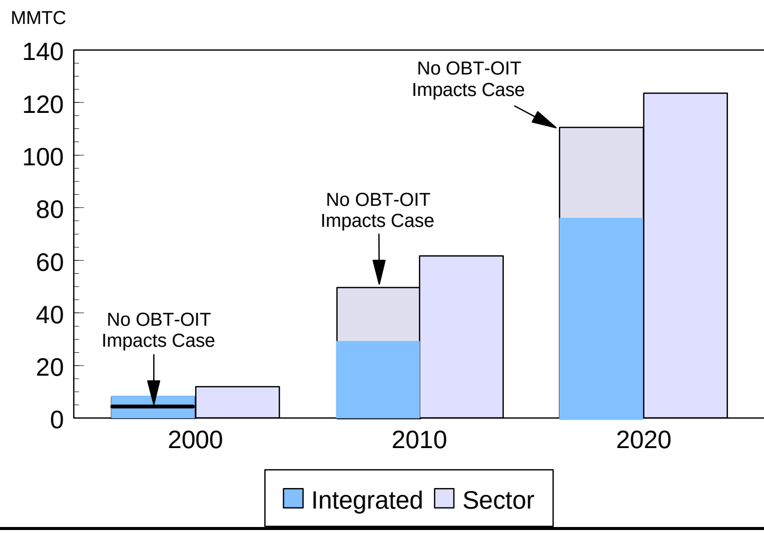
Figure 5-2. Renewable Electricity Capacity in the No_EE Case (GW)



Nationally, electricity conservation will mean that total renewable electricity generation is actually slightly *less* in the years 2000 and 2010 in the Full-EE Case than it is in the No-EE Case, although the mix is different. These reductions are most significant for baseload type renewables, such as MSW and geothermal. However, average fossil fuel use per kilowatt hour of electricity generation is less in the Full-EE Case, which is the main driver of OUT savings. Taken together, end-use conservation efforts forestall much of the need to add new capacity until after the year 2010 in the Full-EE Case. In the years following 2010, new capacity is added quite rapidly and renewables gain significant market share. Two factors help explain part of the acceleration, one is model-based and the other is technology-based. First, the DEGREES model uses perfect foresight. It therefore looks at all years at once and plans the least-total-cost capacity and dispatch to meet demand. Since renewables costs are decreasing over time, the model can choose to wait until the later time periods to install these resources, if it can in the mean time meet demand using existing units. Second, a large percentage of today's generation capacity will be reaching retirement age by the year 2010. Thus, even though the electricity demand rate may be decreasing, the amount of available capacity is also decreasing in the year 2010 and beyond, thereby creating a greater demand for new capacity which can be partially filled by renewable energy technologies.

The energy savings benefits of the OUT programs are expected to result in carbon emissions reductions ranging from 30 to 52 million metric tons of carbon (MMTC) in the year 2010. This figure increases to 76-111 MMTC in the year 2020 (see Figure 5-3). Just as in the energy savings results, the integrated emissions reduction results are lower than the sector results in the years 2010 and 2020 (see the *Issues* section below for details on why this is not the case in the year 2000)..

Figure 5-3. Carbon Emission Benefits of OUT Programs by Integrated Results and Sector Results



METHOD OF ANALYSIS

The integrated analysis included the following OUT planning units:

- Wind Electric Generation
- Photovoltaic Electric Generation
- Solar Thermal Electric Generation
- Biomass Electric Generation
- Geothermal Electric Generation
- Transmission and Distribution Programs
- Integrated Resource Planning

OUT provided documents and data for each of the planning units. We subsequently used these assumptions in the model.

We generated the IDEAS results through an interactive process with the DEGREES model. Initially, IDEAS produced the energy demand figures. We then used these demand figures in the DEGREES model to create the utility profile. In the last step this information was put in the IDEAS model for the integrated run.

We chose the DEGREES model because its central feature is a linear programming (LP) representation of utility capacity planning and fuel dispatch, solved at a regional level of detail. This regional disaggregation is essential to representing potential markets for renewable technologies that differ significantly across regions.

The fact that capacity planning and fuel dispatch are modeled with an LP has several implications:

- The LP chooses new capacity and the use of existing capacity purely to minimize the total discounted cost of meeting demand.

  The LP considers only the capital, fuel, and operating costs of generating resources. Other considerations, such as environmental impacts, that might be imposed on resource choices by regulators or otherwise entered into the process, are not considered.

- Resources that are only slightly cheaper will tend to capture the entire available market.

  The LP does provide information on the relative costs of potential resources that are not, chosen by the model, however. This information has been used to check the plausibility of this kind of "knife-edge" economic decision.

- The model has perfect foresight.

  This means that the capacity plan is constructed with perfect knowledge of future fuel prices and future technology progress. This feature may tend to emphasize strategies that rely on potential technologies such as renewables becoming cheaper in the future.

- The LP treats reliability by using a reserve margin constraint.

  The LP does not have a means of computing loss of load probability, expected unserved energy, or other measures of system reliability, so a reserve margin constraint must be used as a proxy. This procedure has been found to be a reasonable rule of thumb in practical applications.

In computing the energy savings for OUT, we used a relatively simple allocation scheme which is describe in the Appendix A.

ASSUMPTIONS FOR ANALYSIS

The most critical assumptions in the analysis of OUT programs are the technical characterizations of the renewable electric generation technologies. We provide the details for the No-EE Case assumptions and the Full-EE Case assumptions in the tables below (see Tables 5-2 and 5-3).

Table 5-2 OUT No-EE Case Assumptions[10]

(constant capital costs)

Planning Unit	Variable O & M (mills / kWh)	Fuel Cost (yr 2000) (mills / kWh)	+ Fuel Cost (mills / kWh)	Fixed O & M ($ / KW - yr)	Heat Rate (Btus/KWh)	Capital Cost (1990$s / KW) (Constant for all years)
New Wind	0.00	- -	0.00	$24.00	- -	$716
New Solar	0.00	- -	0.00	$32.10	- -	$3,900
New Solar P.V.	2.30	- -	0.00	$0.00	- -	$7,000
Biomass	15.00	35.30	50.30	$32.20	11,750	$1,450
New	-41.90	- -	-41.90	$17.30	15,000	$5,397
New Geothermal	0.00	- -	0.00	$46.90	- -	$3,590
Gas Cogen 1 -	3.96	28.50	32.46	$4.30	9,565	$1,150
Gas Cogen 2 -	3.96	31.92	35.88	$4.30	10,710	$856
Coal Cogen - 85%	4.82	13.14	17.96	$32.10	10,350	$2,782
Gas Cogen 1 -	3.96	28.50	32.46	$4.30	9,565	$1,150
Gas Cogen 2 -	3.96	31.92	35.88	$4.30	10,710	$856
Coal Cogen - 35%	4.82	13.14	17.96	$32.10	10,350	$2,782
Advance Cogen 85%			This plant does not	esit in this case		
Future CCYL	2.20	21.73	23.93	$8.40	7,293	$630
Future C.T.	5.00	39.04	44.04	$0.50	13,100	$351
Advance C.T.			This plant does not	exist in this case		

[10] Assumes capital cost of technology remains constant.

Table 5-3. OUT Full-EE Case Assumptions[11]

(decreasing capital costs)

Planning Unit	Variable O & M (mills / kWh)	Fuel Cost (yr 2000) (mills / kWh)	Fuel Cost (mills / kWh)	Fixed O & M ($ / KW - yr)	Heat Rate (Btus/KWh)	Capital Cost (1990$s / KW) 1995	2000	2010	2020
New Wind	0.00	- -	0.00	$24.00	- -	$716	$691	$674	$657
New Solar Thermal	0.00	- -	0.00	$32.10	- -	$3,900	$2,334	$2,281	$2,060
New Solar P.V.	2.30	- -	0.00	$0.00	- -	$7,000	$3,500	$1,519	$991
Biomass	15.00	35.30	50.30	$32.20	7,000	$1,450	$1,300	$999	$848
New MSW/Landfill	-41.90	- -	-41.90	$17.30	15,000	$5,397	$4,887	$3,971	$3,258
New Geothermal	0.00	- -	0.00	$46.90	- -	$3,590	$2,303	$2,159	$2,015
Gas Cogen 1 - 85%	3.96	28.50	32.46	$4.30	9,565		$1,150		
Gas Cogen 2 - 85%	3.96	31.92	35.88	$4.30	10,710		$856		
Coal Cogen - 85%	4.82	13.14	17.96	$32.10	10,350		$2,782		
Gas Cogen 1 - 35%	3.96	28.50	32.46	$4.30	9,565		$1,150		
Gas Cogen 2 - 35%	3.96	31.92	35.88	$4.30	10,710		$856		
Coal Cogen - 35%	4.82	13.14	17.96	$32.10	10,350		$2,782		
Advanced Cogen 85%	3.96	17.61	21.57	$4.30	5,910		$856		
Future CCYL	2.20	21.73	23.93	$8.40	7,293		$630		
Future C.T.	5.00	39.04	44.04	$0.50	13,100		$351		
Advanced C.T.	5.20	17.81	23.01	$0.50	5,975		$725		

[11] Assumes a decline in the capital cost of technology. Cost estimates are derived from the Office of Energy Efficiency and Renewable Energy technology characterization studies.

The Full-EE Case assumptions generally follow the Technology Characterizations developed by NREL and OUT. Due to OUT updates, biomass and solar thermal technologies are exceptions. In these cases, OUT staff supplied the technology characterizations for these technologies to NREL as part of the Quality Metrics exercise.

We assumed that the Technology Characterization data were consistent with the Full-EE Case, i.e. they represented the technologies as they would exist in a world with OUT programs in place. Several different approaches were available to develop technology descriptions in the No-EE Case. The one finally adopted was to assume that the technology characteristics constant in 1995, as described by the Technology Characterizations, would not improve over time.

We included a number of other relevant assumptions in the OUT program benefits analysis:

- The Advanced Cogen and Advance Combustion Turbine plants only exist in the Full-EE Case, and they are limited to 22,000 MW of capacity in 2010 and 35,000 MW in 2020.

- Biomass has a decreasing heat rate. Since DEGREES cannot emulate this, we reduced fuel cost more than expected to account for the efficiency increase.

- In the Full-EE Case, we accounted for transmission programs by reducing transmission line losses from 7% to 6.8% for transmission within a region, from 5% to 4% for inter-region transmission. In the No-EE Case, we left the losses at 5% for inter-region transmission and 7% for intra-region transmission.In the Full-EE Case, we included DSM estimates in the IRP planning unit. We estimated the savings per year as follows (GWh):

	1995	**2000**	**2010**	**2020**
Estimated Savings per Year	36,643	72,741	142,103	179,610

By assumption, We included only 75 percent of the DSM that occurs in the Full-EE Case in the No-EE Case.

ISSUES

Integrated modeling of OUT planning units raises a key interaction issue. In the OBT-OIT Impacts Case, the OBT and OIT conservation programs significantly reduced the impact of OUT programs in the years 2010 and 2020 (see Table 5-4). This does not occur in the No OBT-OIT Impacts Case. In the years 2010 and 2020, the interaction effect reduces the impact of OUT programs by around 20 percent. Interestingly, this is not the case in the year 2000. In that case, the OBT-OIT Impacts Case actually had a larger energy savings than the No OBT-OIT Impacts Case. This is because in the latter case, the energy consumption in the utility sector is 0.37 quads less than in the No-EE Case, and the entire change is attributable to OUT programs. In the OBT-OIT Impacts Case, however, energy use is only 2.7 quads less than in the No-EE Case. The allocation scheme attributes 23 percent of these energy savings (0.63 quads) to OUT. This illustrates that the allocation described above is necessarily imprecise, particularly for relatively small energy savings. As further illustration, consider a "bottom-up" estimate of OUT savings in 2000, developing estimates for renewables, IRP, and T&D programs independently and adding them. This method yields a net OUT savings of 0.19 quads, smaller than both the other estimates.

Table 5-4. Interaction Effect and OUT Savings (quads)

	2000	2010	2020
OBT-OIT Impacts Case	.63	1.12	3.44
No OBT-OIT Impacts Case	.37	1.46	3.77
% Impact of Interaction	-41%	30%	10%

We present the source of differences between the DEGREES estimates and the OUT estimates in Table 5-5. Note that the OUT energy savings subtotal for the No OBT-OIT Impacts Case actually shows a lower savings in the year 2000 than the OBT-OIT Impacts Case estimate which includes the interaction effects. In the years 2010 and 2020, however, the OUT energy savings subtotal of the No OBT-OIT Impacts Case is larger than the DEGREES estimate including the interaction effects, although the difference is within one quad.

One complication that contributes to the unexplained differences is the way the integrated model calculates savings for renewables penetrations. At first glance, the most natural accounting convention appears to be to credit renewables with the system average heat rate (in terms of *fossil fuels* per unit of electricity generation.) However, this may tend to overstate the actual energy savings because the change in fossil fuel use due to renewables penetration is not accurately represented by the system average fossil-fuel heat rate since renewables do not displace average plants. They displace generation from the plants which would have been installed in their place in the No-EE Case. These plants tend to be more efficient than the system average, so that using the system average to compute the displacement from renewables penetration would overstate the savings.

Table 5-5. Comparison OUT Energy Savings Between OUT and DEGREES Estimates (quads)

	2000	2010	2020
OUT Only Case Estimate	0.4	1.5	3.8
OUT Estimates of Programs not Modeled in DEGREES	0.0	0.4	1.2
Subtotal: No OBT-OIT Impacts Case	0.4	1.9	5.0
Comparable OUT Estimate of Total Impacts	0.8	3.9	7.4
OBT-OIT Impacts Case (DEGREES Estimate)	0.6	1.1	3.4

APPENDIX A. OUT ENERGY SAVI NGS ALLOCATION SCHEME

The OUT energy savings were computed using model results for the change in the fossil-fuel energy used in electricity generation as composed by the following factors:

D, the demand for end-use electricity in the No-EE Case,
ΔD, the change in demand between the No-EE and Full-EE Cases,
H, the average amount of fossil fuel consumed in the generation of on kWh of electricity.

H has the units of a heat rate, but is computed slightly differently because it only counts fossil fuels. This definition allows the *fossil fuel* savings to be computed directly as seen below.

ΔH, the change in H between the No EE and Full-EE Cases.

Now the fossil fuel use in electricity generation in the No-EE Case, $E_{No\ EE}$, can be written as

$$E_{NoEE} = D \cdot H$$

and in the Full-EE Case, it is simply

$$E_{FullEE} = (D - \Delta D) \cdot (H - \Delta H)$$

The energy savings are just the difference between these two amounts,

$$\Delta E = D \cdot \Delta H + H \cdot \Delta D - \Delta H \cdot \Delta D$$

Except for the adjustments described below, OUT is responsible for the programs that change the factor H, such as renewables, and the end-use sectors are responsible for programs that change end-use demand, D. The natural allocation is then to attribute

$$\Delta E_{EndUse} = H \cdot \Delta D - \frac{\Delta H \cdot \Delta D}{2}$$

to the end-use sectors and

$$\Delta E_{OUT} = D \cdot \Delta H - \frac{\Delta H \cdot \Delta D}{2}$$

to OUT programs. The interaction term ΔHΔD (which is small) has simply been split between OUT and the end-use sectors. In practice, the above calculation is done separately for OBT and for OIT electricity demand, and the results for E_{OUT} added together.

After this has been done, two different adjustments are required. The first one allocates the par of the impacts of utility DSM programs, part of OUT's IRP program, to OUT. (Since they change demand, the above conventions allocate them to OBT). In this exercise we allocated 50% of utility DSM program impacts to OUT program initiatives. A second adjustment reallocates the impacts of the OIT Advanced Turbine program to OIT (since it reduces the heat rate of electricity generation, the above procedure allocates these impacts to OUT.)